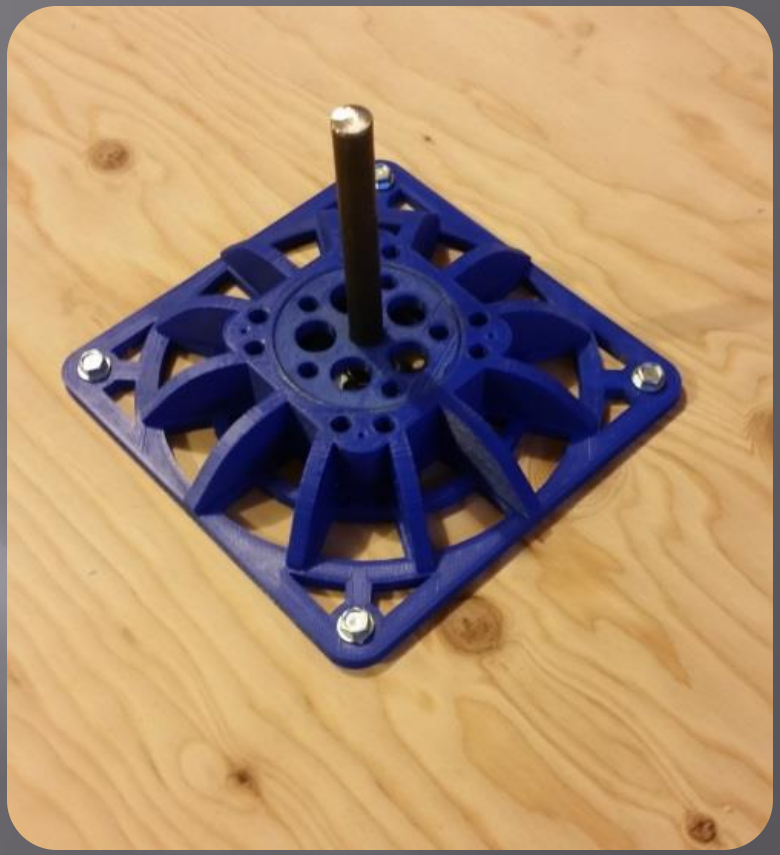
ROBOT ASSEMBLY INSTRUCTIONS

Note: there are many components that will require trimming / sanding ext. I have tried to model all the components to be best fit and made corrections as I went along. There are likely some differences depending on the printer you are using. Please let me know if you find any issues that need to be addressed. chris.annin@gmail.com

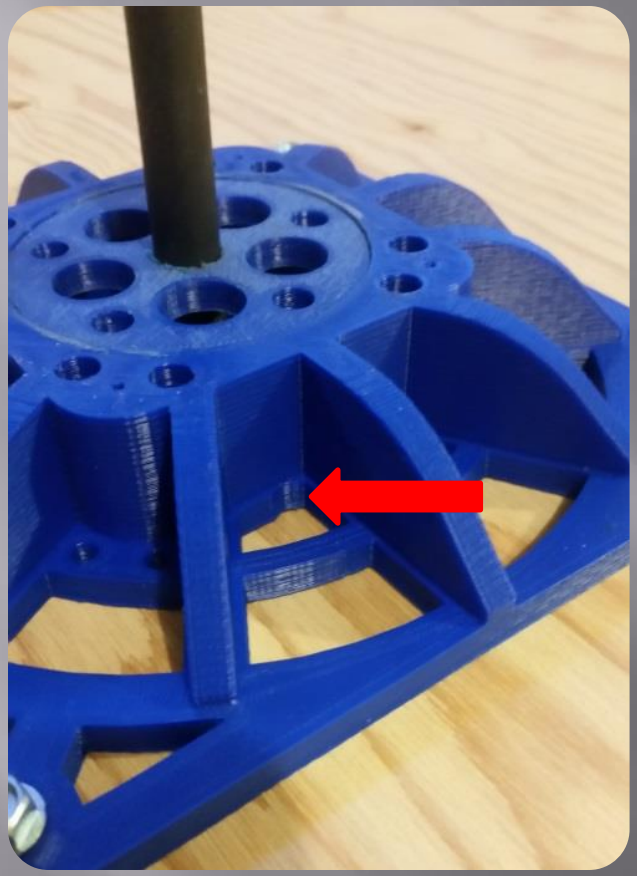
1) Drill a ½″ hole in center of plywood sheet approx. 16″ to 18″ from one end. This will be the center location for your robot – you can place the center wherever you like just make sure you leave yourself enough room on one side or the other for your working envelope.

2) Cut the head off of a ½″ bolt as shown. make sure there is enough exposed threads to go through a ¾″ thick sheet of plywood with washers and nuts while still leaving the shaft end 5″ up from the top of the board.

3) Insert bolt through plywood and tighten nut on opposite side.

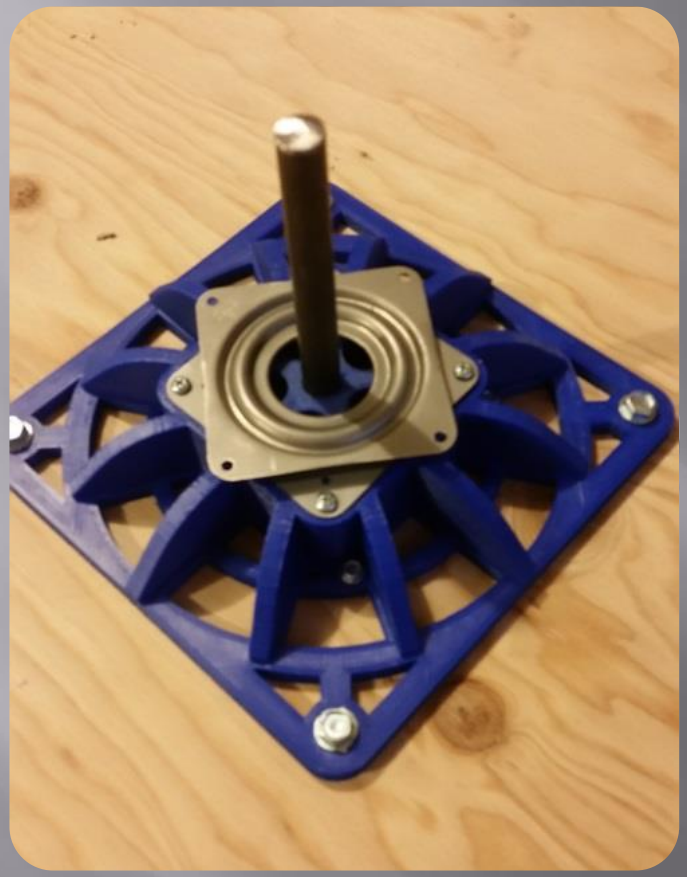


4) Epoxy J1 alignment ring into J1 base. Place base assembly over center bolt, make sure the base is square to the board and then use #14 Screws to secure the base to the table.

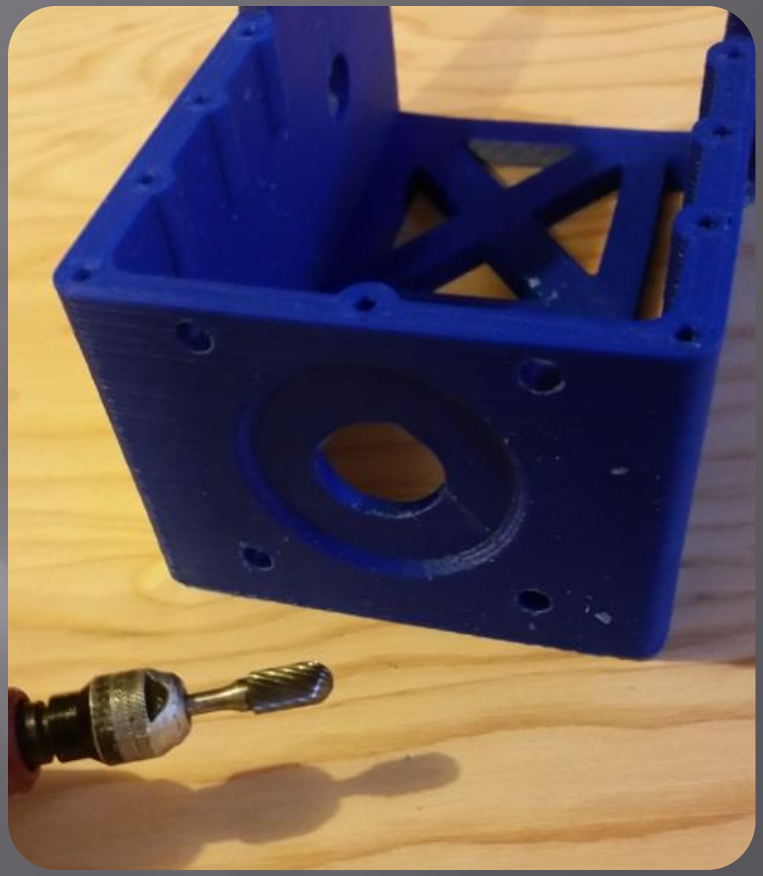


5) Identify the alignment cutout shown above near the center of the J1 base.

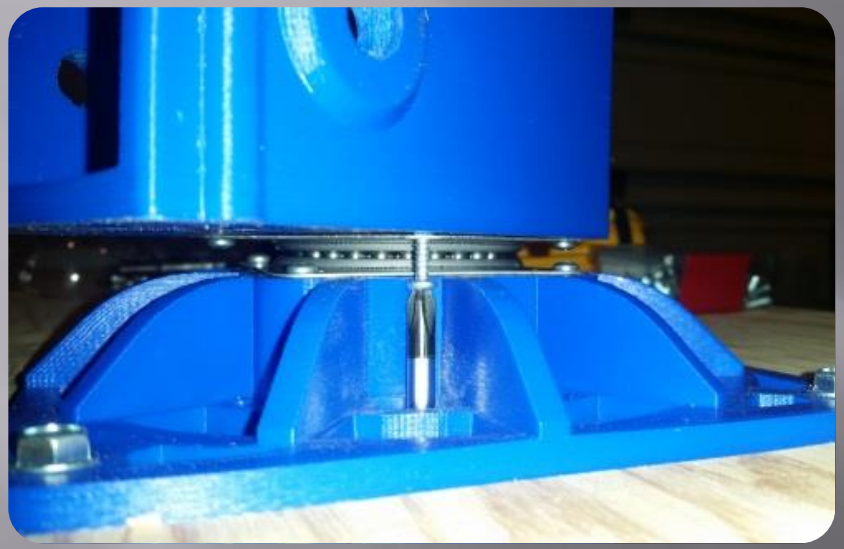
6) Drill a hole through the plywood that is concentric or aligned with the alignment cutout in the base.



7) Use #6 screws to attach the lazy Susan to the base.



8) Use a rotary tool with attachment similar to the one shown above to clear out the window supports / cutouts in 3 different places.



9) Attach J1 turret to the base using #6 screws. You will need to rotate the turret to align with Relief hole and insert screw driver from below.

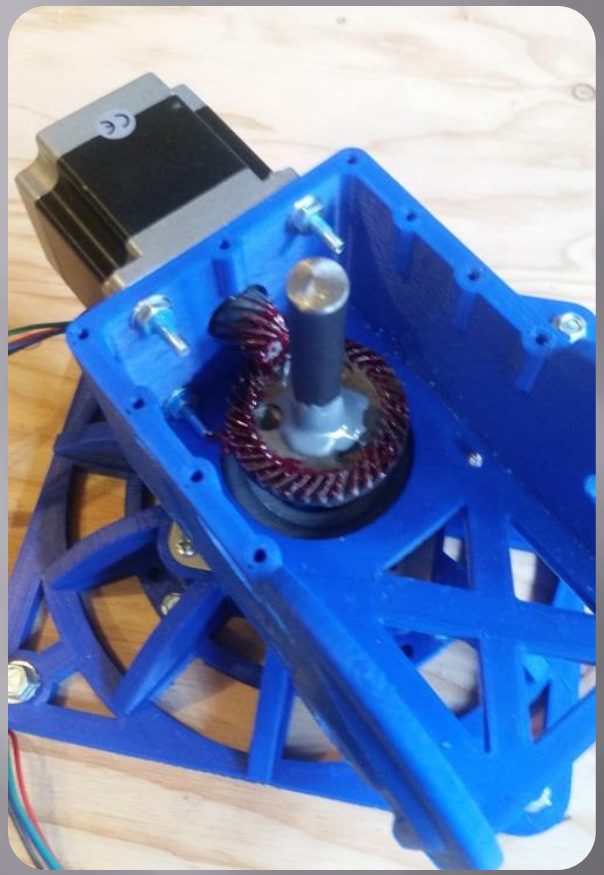
10) I chose to use a ½" center bolt due to the fact ½" hardware was easier to acquire. the center of the bevel gear is actually 12mm so I had to use the rotary attachment shown above to slightly enlarge the hole in the gear. the gear is hardened so you cannot drill it. You can substitute 12mm hardware if you like I just couldn't find any 12mm bolts long enough at any local hardware stores and I didn't want to deal with ordering a single bolt.

11) The spiral gear is also slightly too small to fit over the shaft of the nema 23 stepper motor so again I used a small rotary stone to slightly open up the hole until it fit the shaft I used epoxy (JB weld) to secure it to the shaft.

12) Install a ½" shaft collar as shown. This shaft collar is a rest to help you set the height of the bevel gear. You will be raising or lowering this shaft collar until you get the backlash or mesh of the bevel gear and the J1 motor spiral gear just right.

13) Install the bevel gear over the shaft then install the motor, place a small amount of pressure on the J1 turret so there is pressure on the lazy susan bearings and then check the Backlash or mesh of the gears. If they feel too tight remove gears and lower the collar and try again. If too loose raise the collar, keep adjusting Until the backlash doesn't restrict motor rotation but doesn't have any play.

14) After you are certain the bevel gear is at the correct height and your gear backlash feels good apply epoxy (JB weld) around the ½" bolt above the collar and then slide the bevel gear down into the epoxy making sure the bevel gear is flat and firmly seated against the collar. You can also apply additional epoxy above the bevel gear as shown above.



15) Install the nema 23 stepper motor using #8 machine screws. Apply grease to the gears.

16) Install the ½" bearing into the J2 left arm.

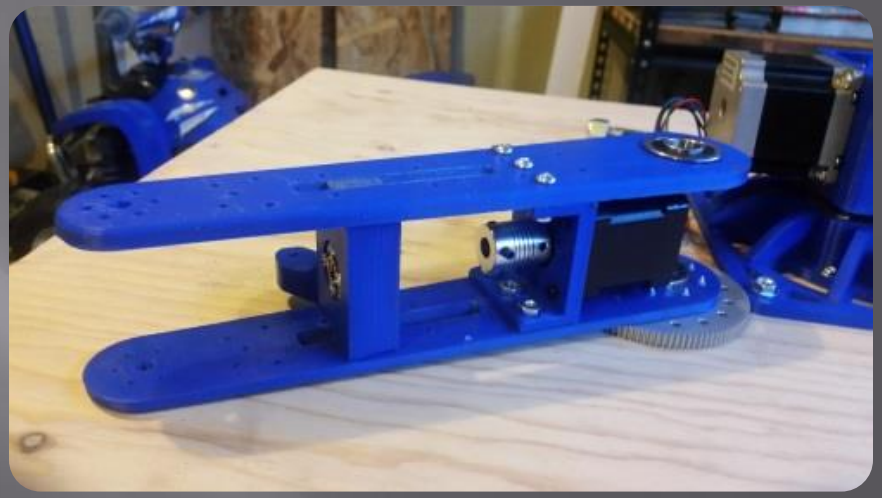
17) Install the 100 tooth gear onto J2 left arm as shown using short #6 screws – note: 4 of the holes in the gear are larger so the shank of the Screw doesn't fit tight in these 4 holes, just the head of the screw shoulders up to these larger 4 holes.

18) Install ½" bearing into J2 right arm as shown.

19) Install the 5mm to 8mm coupling onto nema 17 motor shaft as shown.

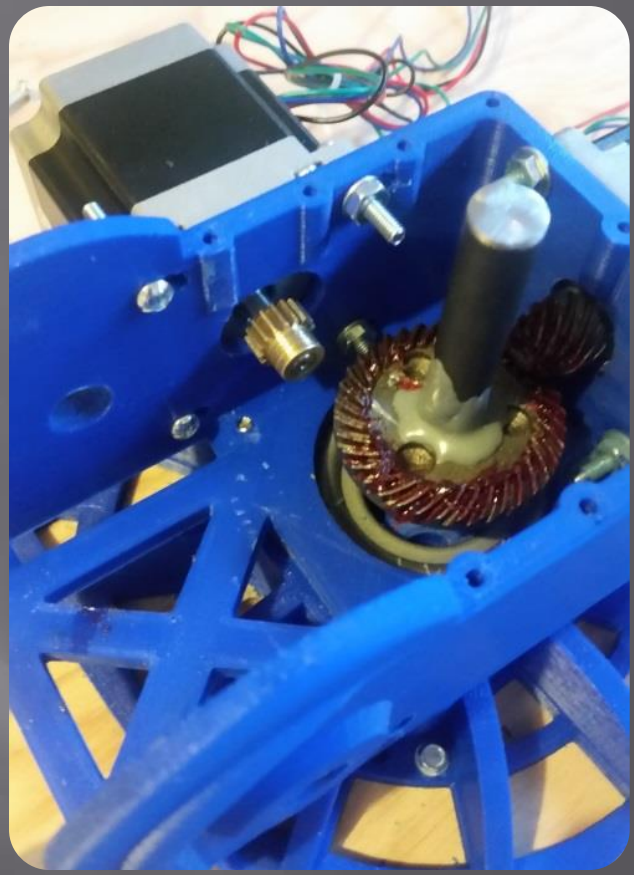
20) Use 3mm screws to attach nema 17 motor to the J2 Motor Support – make sure wires are facing back as shown.

21) Install and epoxy in place 2 square nuts on both sides of the J2 drive block – make sure they are spaced correctly by threading 5/16” rod through both nuts before epoxy sets and making sure the rod turns easily and smoothly.

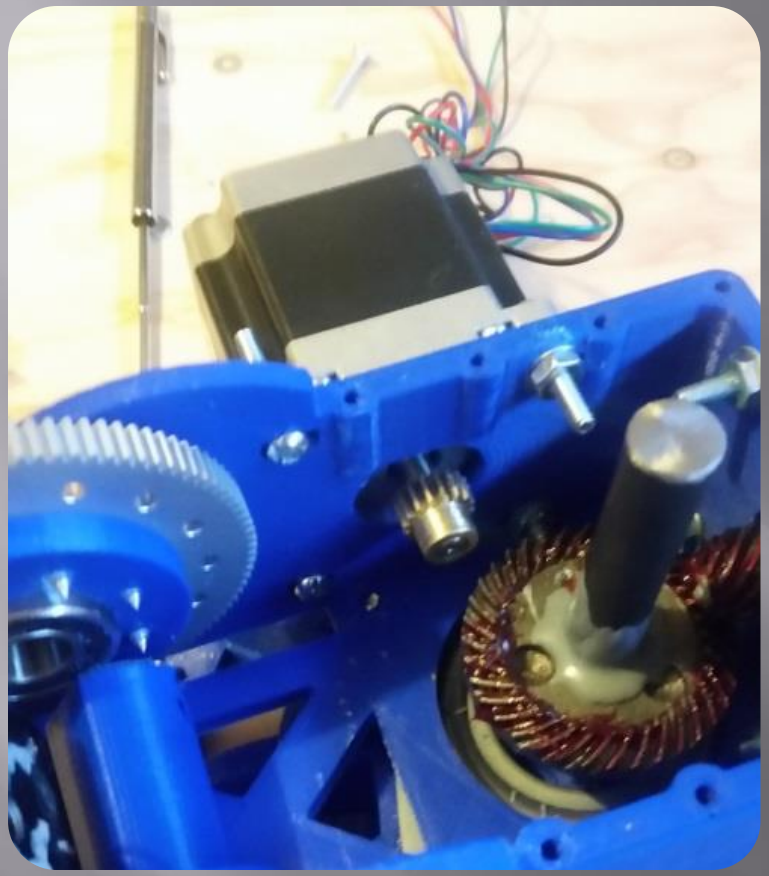


22) Use #6 machine screws to assemble the motor support to the J2 left and right arms as shown – make Sure you also insert the drive block in the slots. Flat file the slots and the drive block to make sure it slides smoothly in the arms but make sure its not loose either.

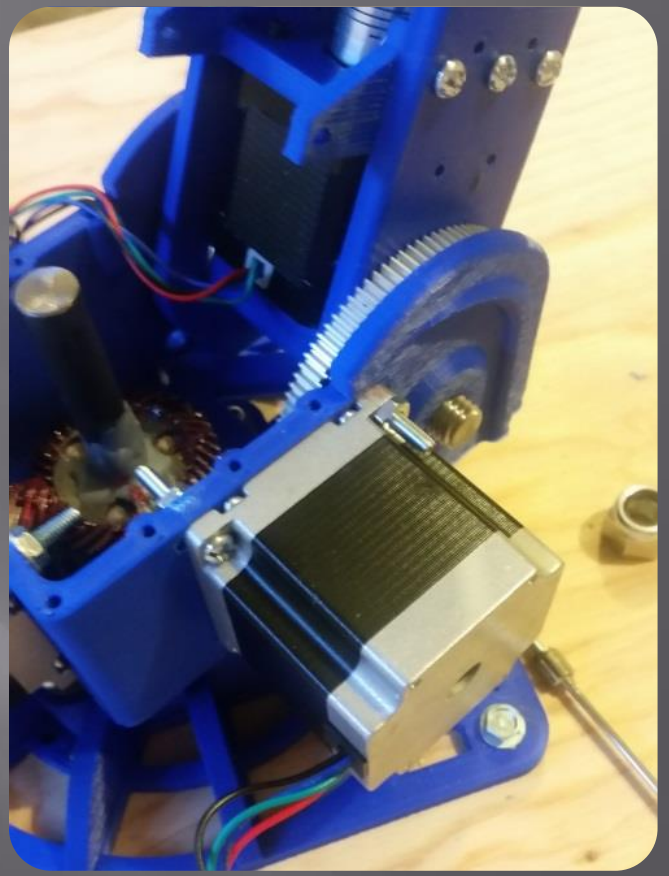
23) Drill the bore of the 16 tooth pinion gear to ¼" and then install on nema 23 stepper motor as shown.



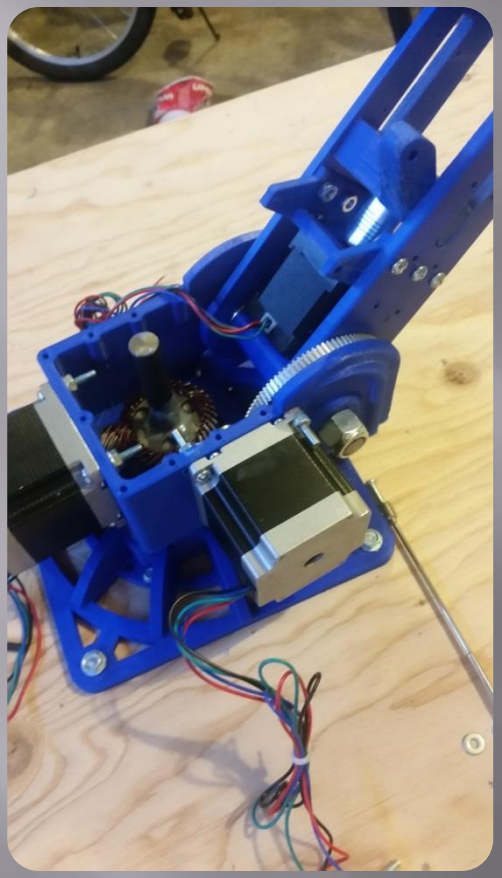
24) Install the nema 23 stepper motor into J1 turret using 8mm machine screws as shown – make sure the 2 forward Screws are head side in, leave the screws slightly loose so gear tension can be set.



25) Position the J2 arm assembly and the J2 spacers as shown (note the thin spacer not shown is on the opposite side of the 100 tooth gear)

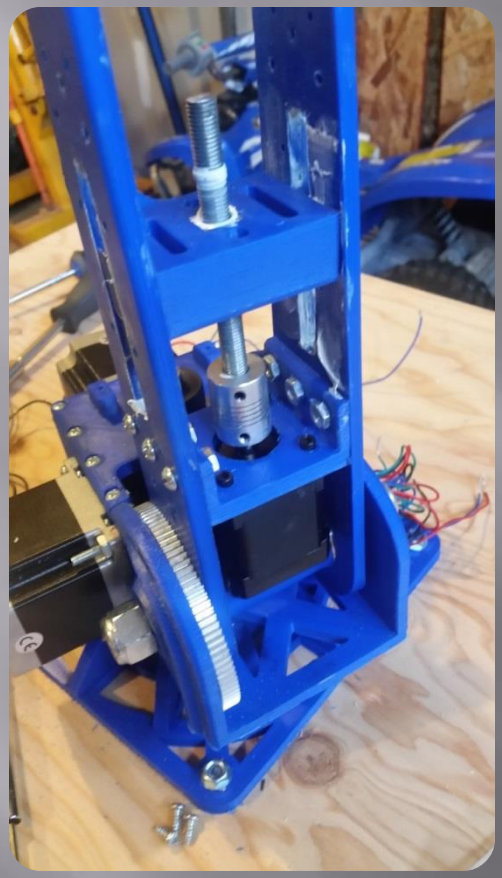


26) After the arm and spacers are in position install a ½″ bolt but do not install nuts or tighten yet.



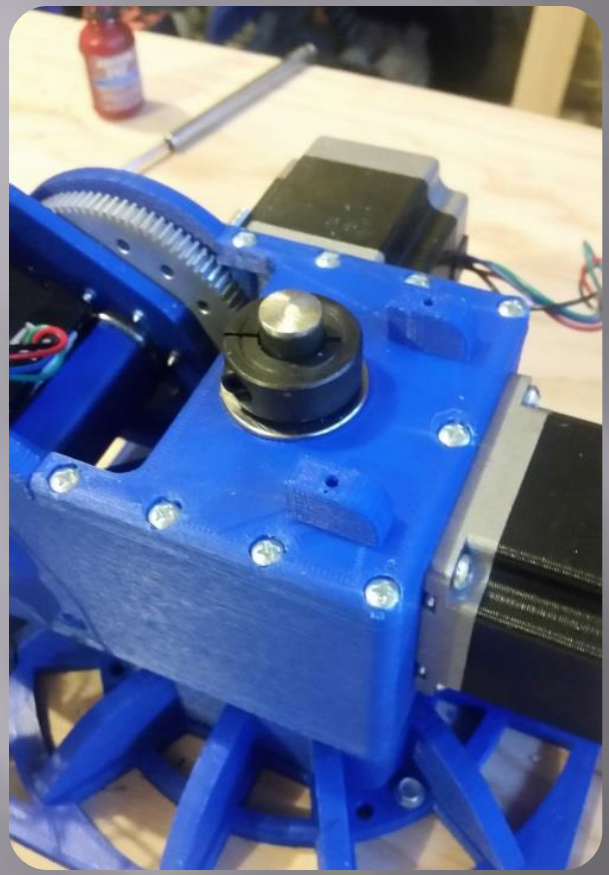
27) With arm assembly in place adjust the backlash of the gears by sliding the motor Closer to the 100 tooth gear. Once you are happy with the backlash tighten the left 2 machine screws on the motor –you will then have to remove the arm assembly and tighten the other 2 motor mount screws – then re-install the arm assembly and install bolt and nut (do not overtighten).

28) Cut a length of the 5/16 fine thread rod to 3.5″ long.



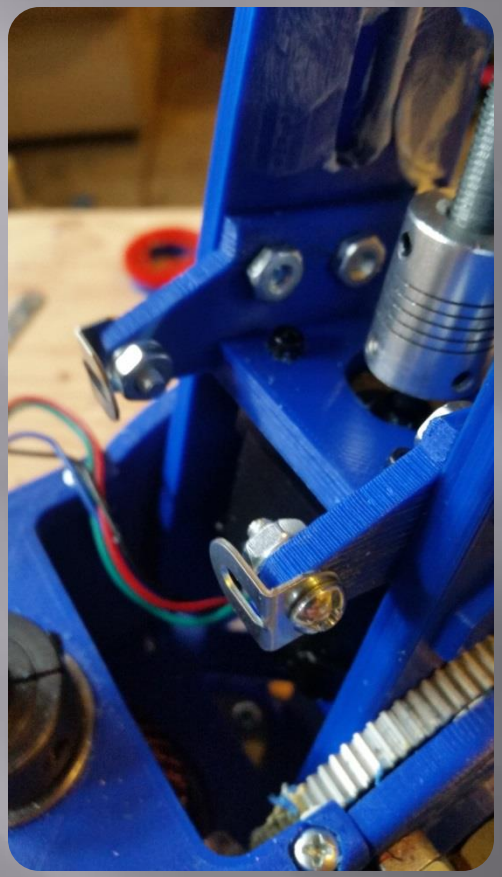
29) Install 5/16″ thread rod by threading through J2 Drive block on inserting Into the coupler on the Nema 17 stepper motor.

30) Install ½″ bearing into J1 turret cover.

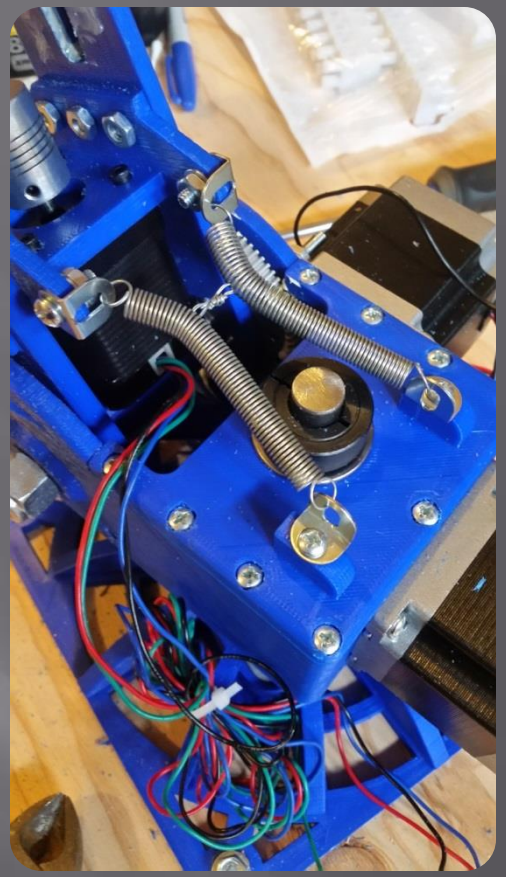


31) Install J1 turret cover and secure with 9 #6 screws. Install ½" shaft collar, apply slight pressure and tighten shaft collar so that collar and cover assembly are pushing down and keeping tension on the lazy susan bearings below.

32) Install angle corner plates as shown on turret cover using #6 screws.



33) Install corner brackets on J2 motor support as shown using #6 machine screws.



34) Install springs from the angle Brackets on the turret cover to the motor support – this will allow counter balance for the J2 arm. Use some wire Between the springs to pull them together and out of alignment - If they are not pulled out of alignment the spring coils will stack up and jam J2 from moving back.

35) Install needle bearings in the J3 turret.

36) Install ¼″ bearings on opposite sides of J3 turret.

37) Install ¼″ dowels in top center holes of the J2 arms.

38) Install the J3 turret as shown and drive ¼″ dowels fully into the ¼″ bearings in the J3 turret.

39) Use short #6 screws to secure side plate covers on both sides.

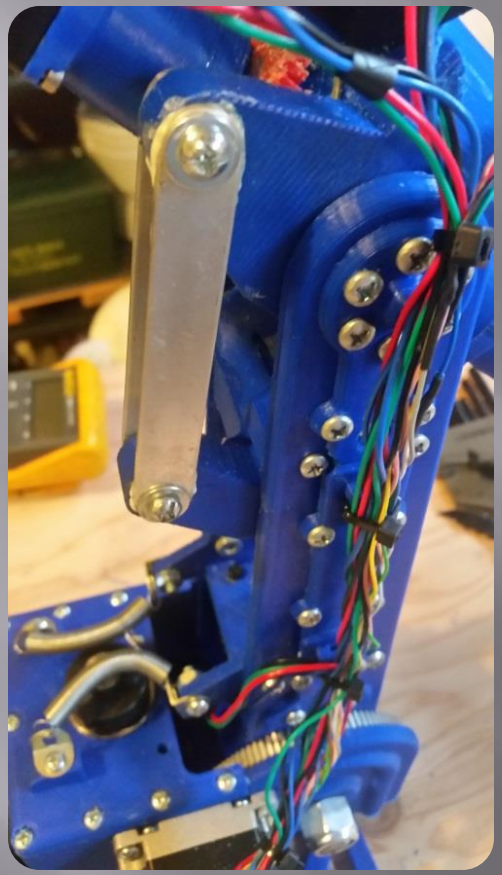
40) Cut 2 lengths of aluminum flat bar Long enough to create 2 arms with holes That are 3″ apart. Holes on one arm should be #18 drill or sized for a close fit on a #8 machine screw. The other arm they should be drilled with a #29 or sized to tap for #8 machine screw.

41) On the arm #1 drilled with the smaller hole – tap the hole for a #8 machine screw.

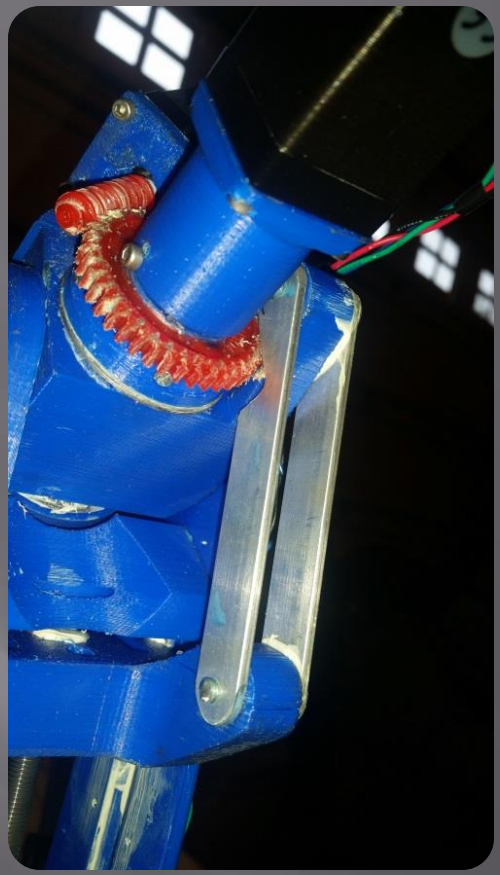
42) On the other arm #2 with the larger holes drilled you will need to notch the bar as shown – the V of the notch should be 1″ from the end.

43) The V of the notch should be 1/4″ from the side

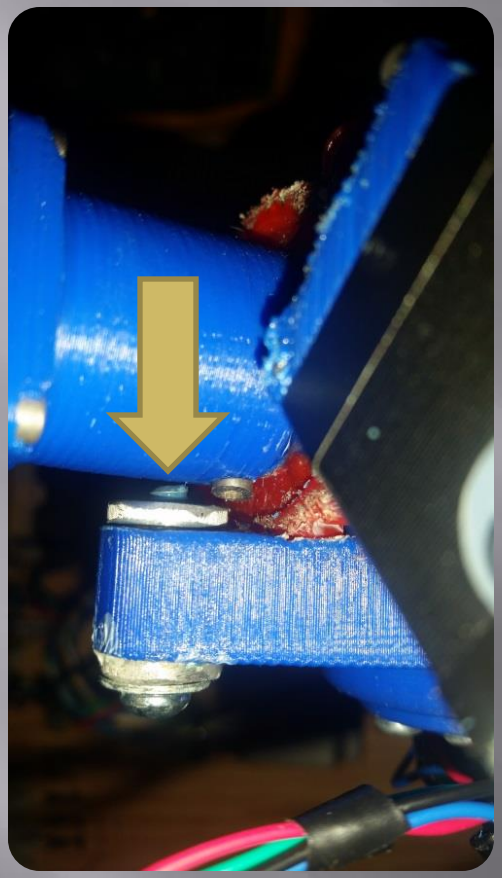
44) Completed Arm #2



45) Install the bars between the J2 drive block and the J3 turret as shown using #8 machine screws. Make sure to grease the screws and contact points of the aluminum arms.



46) This picture is taken further along in the assembly to show where the V notch clearance is needed.



47) Make sure to cut down the #8 machine screws so they do not extend past the aluminum arms – you can see in this picture Where there is a clearance issue.

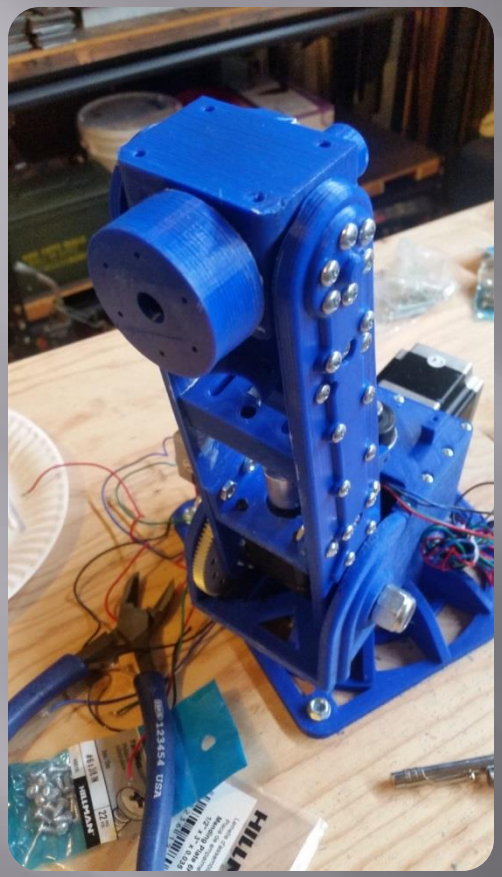
48) Cut a length of the 1″ tubing from McMaster Carr down to 1.9″ long. This tubing was slightly too large in diameter to fit through the needle bearings on the J3 turret so I held the length of tubing up to a belt sander allowing it to spin on a wood dowel and ground the surface down slightly so it would fit. You can see in the next picture the surface is shiny where I ground it. You could try different tube options from McMaster or alternate suppliers with slightly small OD – I chose to grind down the tube I had.

49) Epoxy the tubing onto the J3 spindle as shown. Note the surface was ground down slightly to fit into the needle bearings.

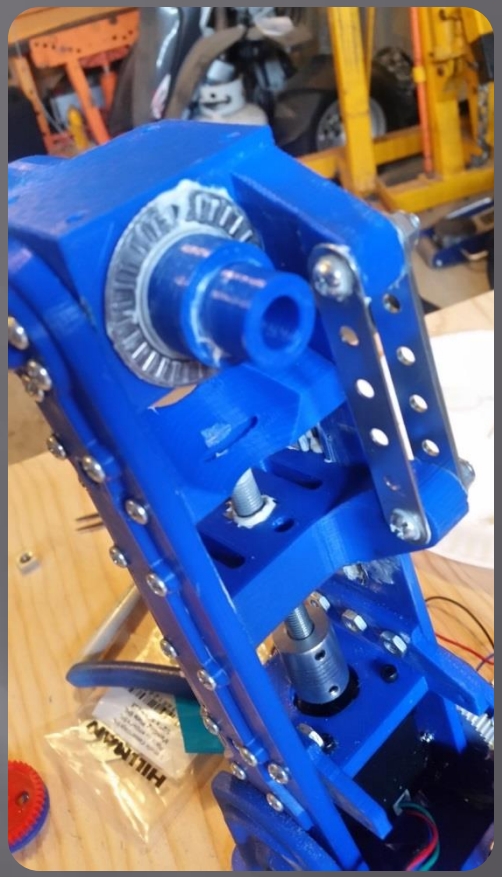
50) Install one of the thrust bearings and apply grease to the bearing.

51) Apply grease to needle bearings in the J3 turret.

52) Insert spindle assembly as shown into the J3 turret.



53) Push the spindle assembly all the way in until its fully seated.

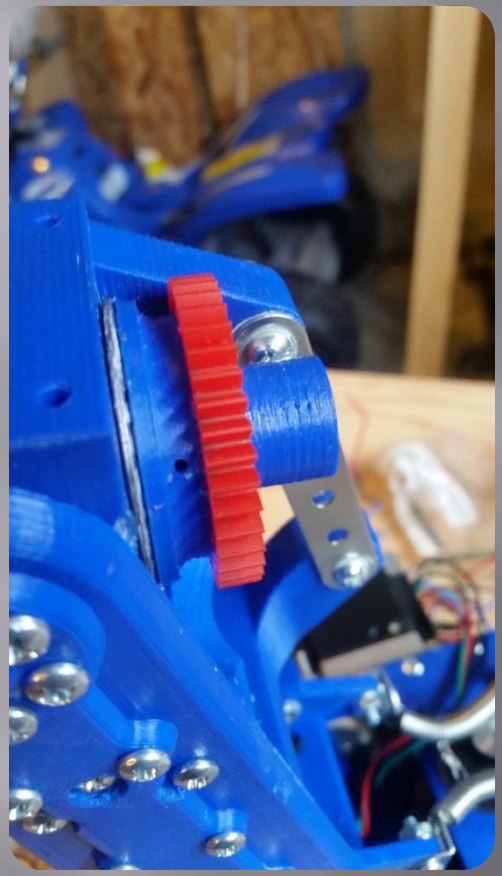


54) Install the thrust bearing as shown and apply grease to thrust bearing. *(note this pic shows different metal support bars I tried but ended up replacing with the custom made aluminum ones)*

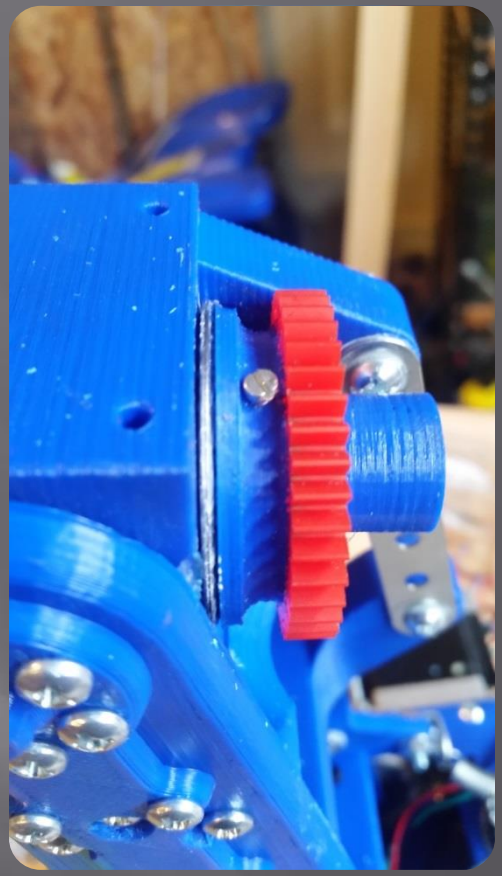
Cut the center out of the 1.6″ Diameter gear as shown using a rotary tool.

Heavily sand and scratch the Surface of the gear and then Use JB weld to epoxy the gear To the 1″ Collar printed part.

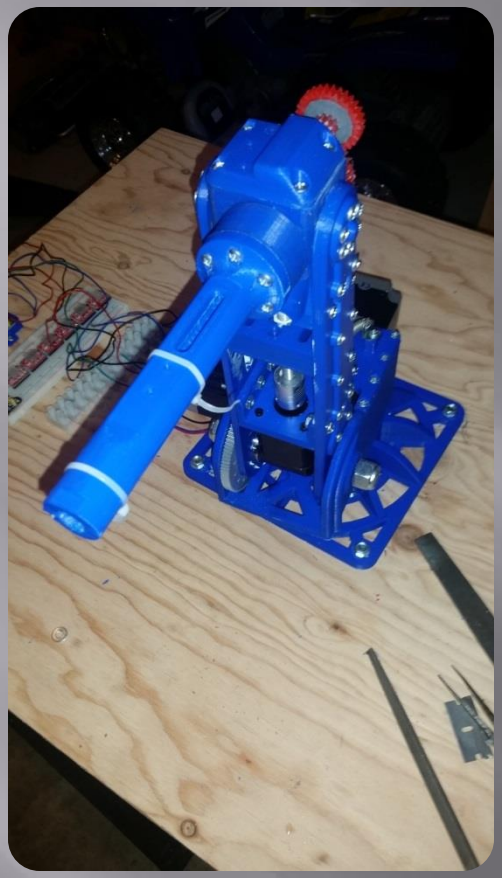
After epoxy is completely cured use rotary tool to grind gear to match inner diameter of the 1″ collar .



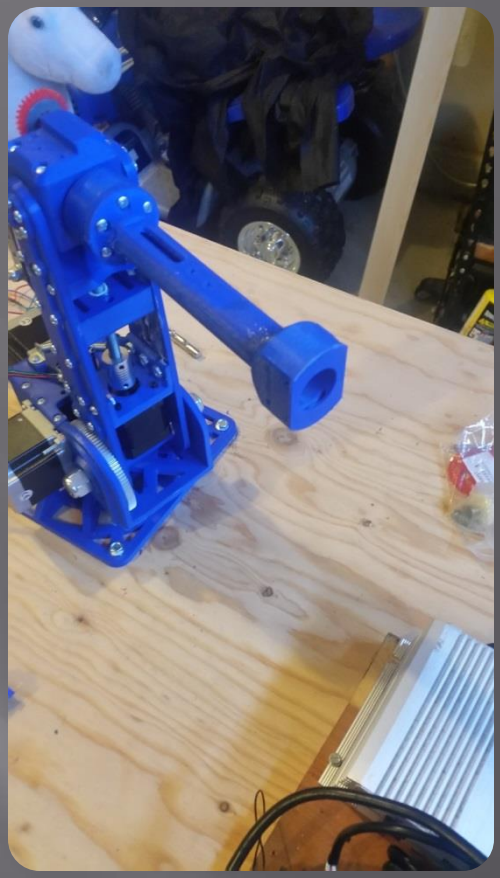
55) Insert J4 gear assembly
Onto spindle, apply pressure
Making sure there is no play
In the thrust bearing and then
drill a small hole as shown
through the collar and spindle
(hold should be just smaller than
2mm – or screw to be used)



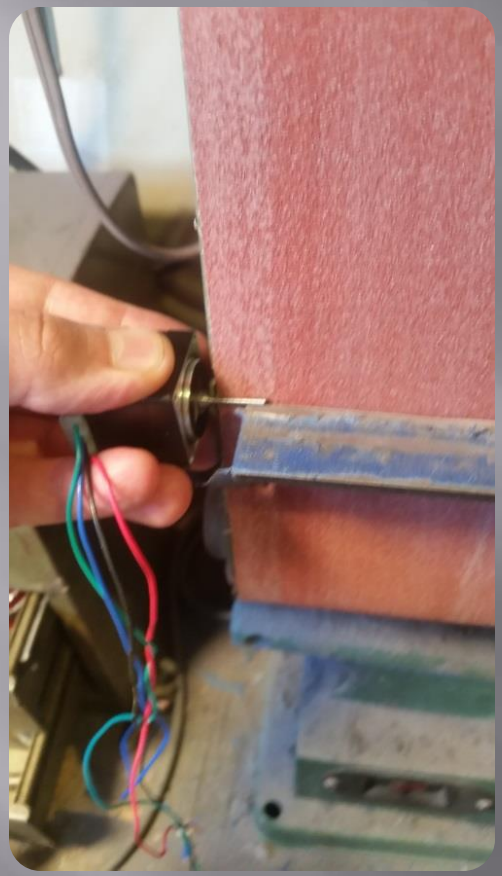
56) Drive small 2mm screw
Into hole to pin the J4 gear
Assembly to the spindle.
Drill and insert screw evenly
Spaced in 3 more places so
You have a screw every 90°.
Make sure screw is not too long
and doesn't extend into center
of spindle.



57) Epoxy J4 boom shaft halves together and install as shown. use zip ties to hold them together while epoxy sets.

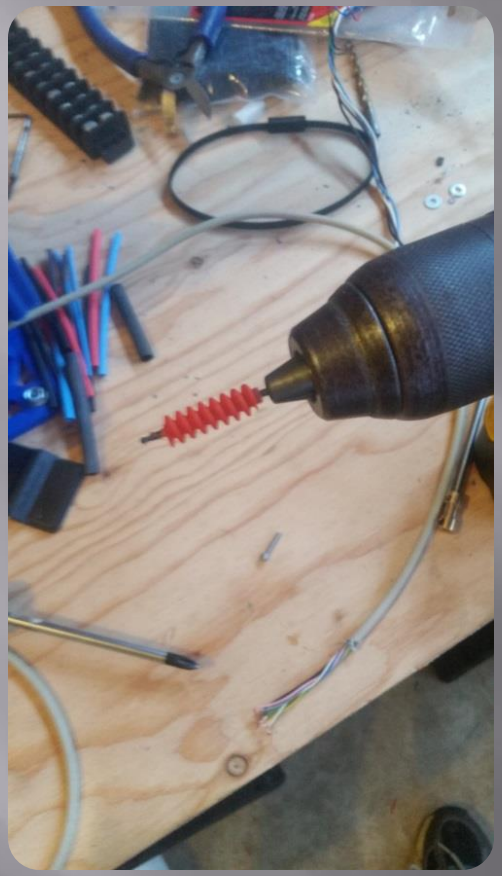


58) Epoxy the J5 clevis center to the end of the J4 boom. Note there is a notch / flat on the end so it only clocks on one direction.



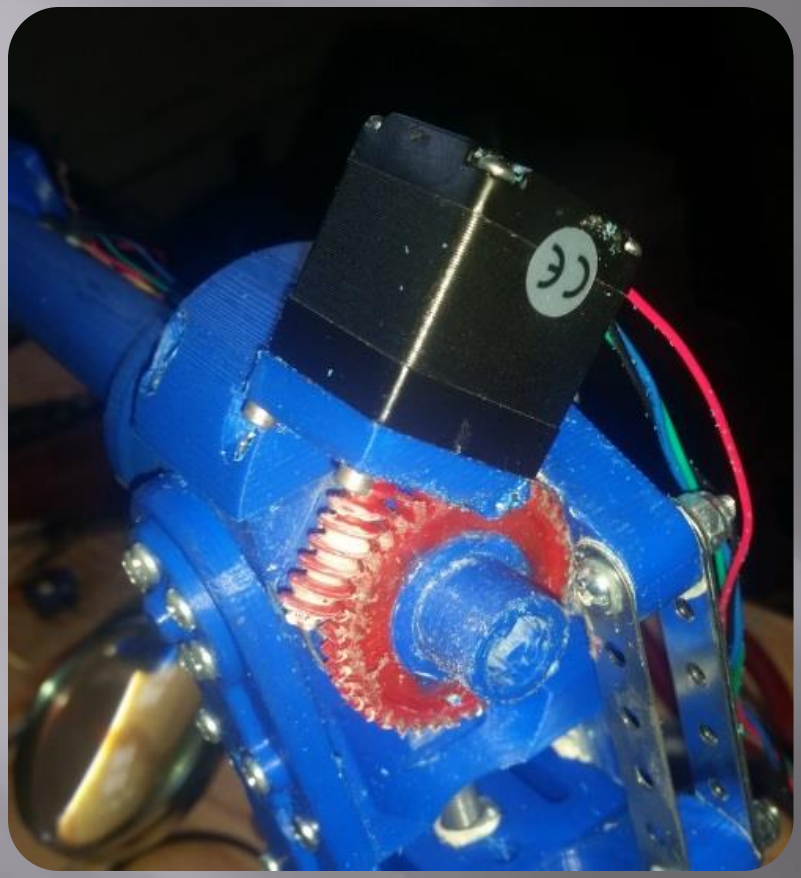
59) I wasn't too thrilled with this method but given the size of the components and what was needed this was the best solution I found. Hold The shaft of the nema 11 stepper motor for J4 up to A belt sander at a slight angle allowing the sander to grind the shaft while the shaft is spinning, the belt will spin the shaft but it will also grind the shaft as it spins, this takes some time – keep the shaft cool with A damp towel, go slow and be careful.

60) Grind shaft down until its .075" in diameter.



61) Drill plastic worm gear to .075″ bore.

62) Use JB weld to epoxy worm gear onto motor shaft.



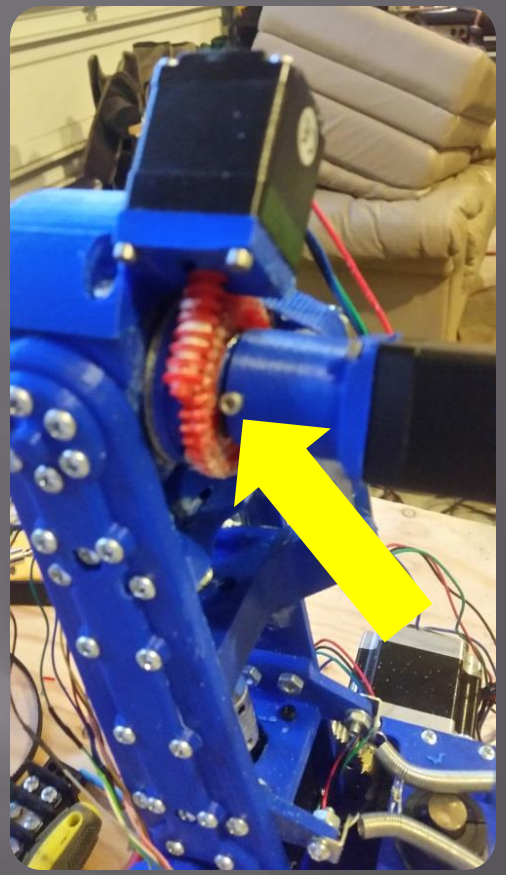
63) Install J3 turret cap and motor assembly as shown – adjust turret cap so that there is minimal backlash between worm gear and ring gear.

64) Epoxy one end of the 4mm shaft into the female end of the metal EBay worm gear, then cut the shaft So that the entire assembly measures 5.3″ long.

65) Attach the worm drive extension to the nema 11 motor for axis 5 using the 4mm to 5mm coupler.

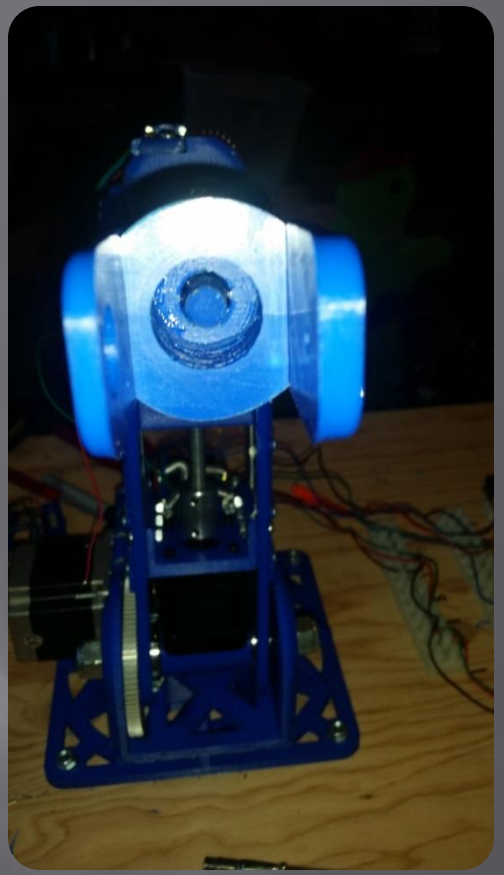
66) Attach the J5 motor mount to the nema 11 stepper motor.

67) Insert the J5 motor / shaft assembly as shown.

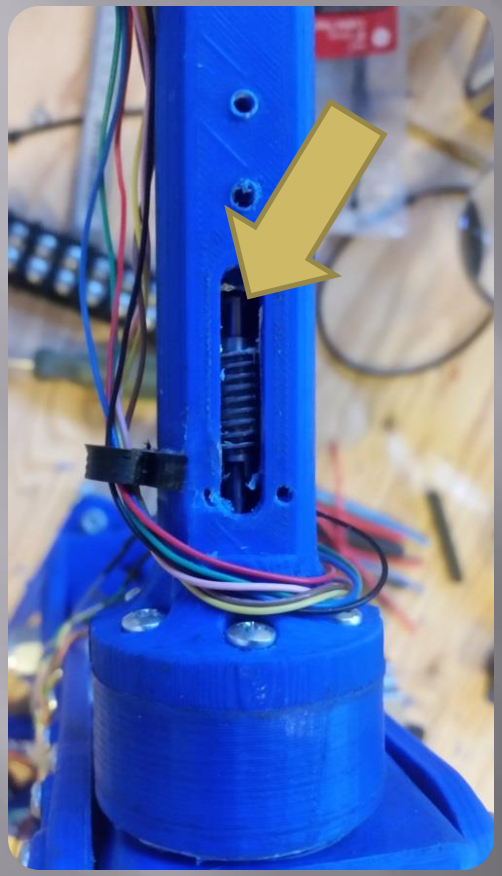


68) Drill 4 holes 90° apart and pin motor mount to spindle using 2mm screws as was done in step 56. Make sure screws are not too long and do not contact internal shaft.

69) Apply some grease into the end of the worm bushing,



70) Install the worm bushing Into the end of the J4 boom and then use a rod to push it all the way down until it mates with the end of the metal worm drive extension.



71) Once the bushing is Seated over the end of the Metal worm drive gear place A few drops of super glue where the arrow is pointing to secure the bushing to the boom.

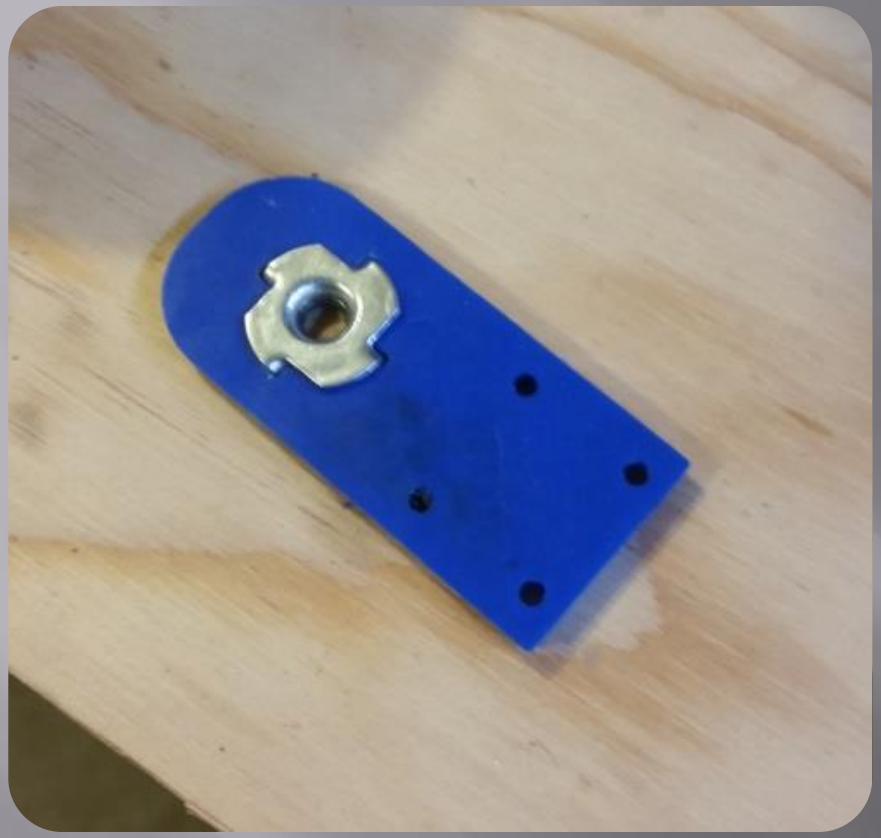
72) Epoxy the small metal coupling to the shaft end of the EBay gear as shown. Note: the coupling needs to be epoxied to the shaft upside down or the opposite direction of what is normally intended for this item.

73) Install the EBay gear assembly and J5 carrier and cap as shown using #6 machine. You will need to sand the bottom of the carrier to set the backlash between the worm gear inside the boom and the ring gear held by the carrier.

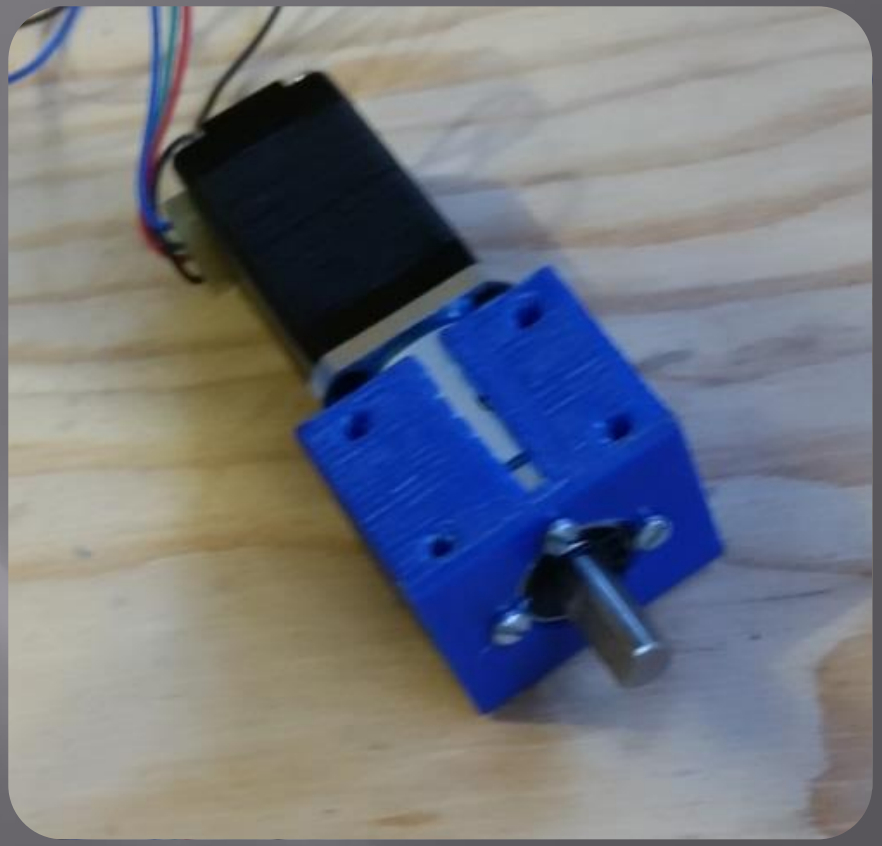
74) Install ¼" bearing into left clevis arm, then install left and right clevis arms to center using #6 screws.

75) Place ¼″ plywood T nut onto end of bolt And then sand down to .185″ thickness.

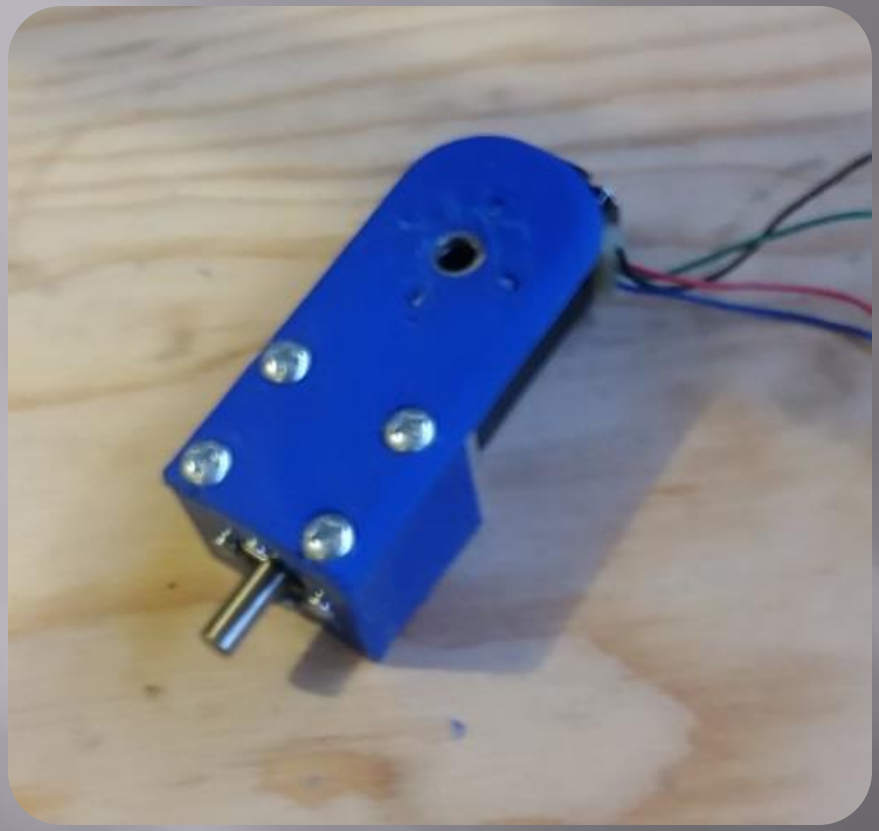
76) Grind down to .185″ thick.



77) Insert T nut into J5 turret left arm.

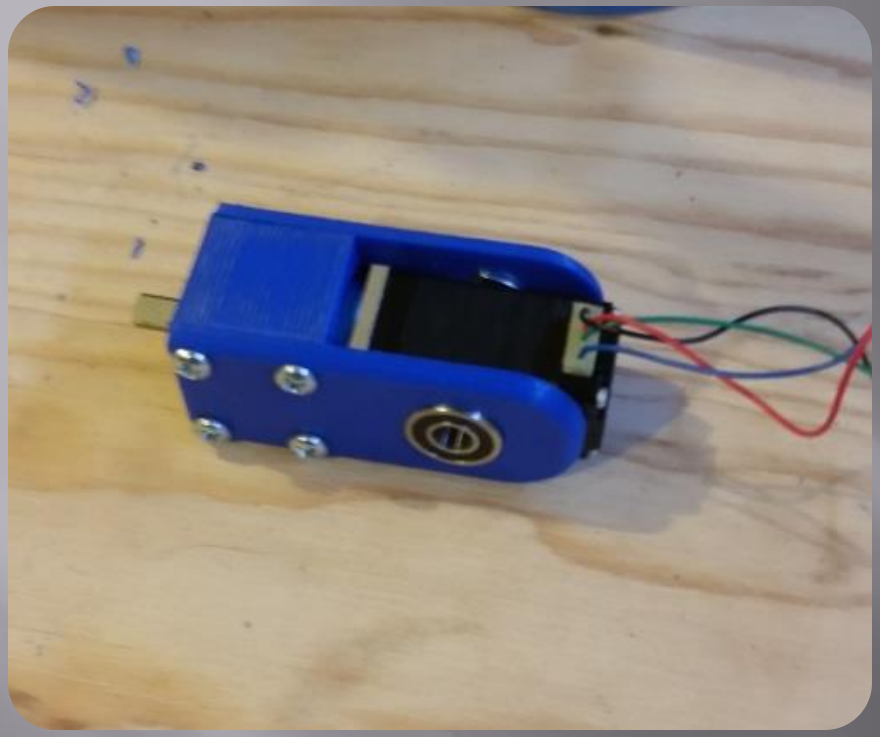


78) Install J6 nema 8 stepper motor with planetary gear drive into the J5 turret using 2mm screws as shown.

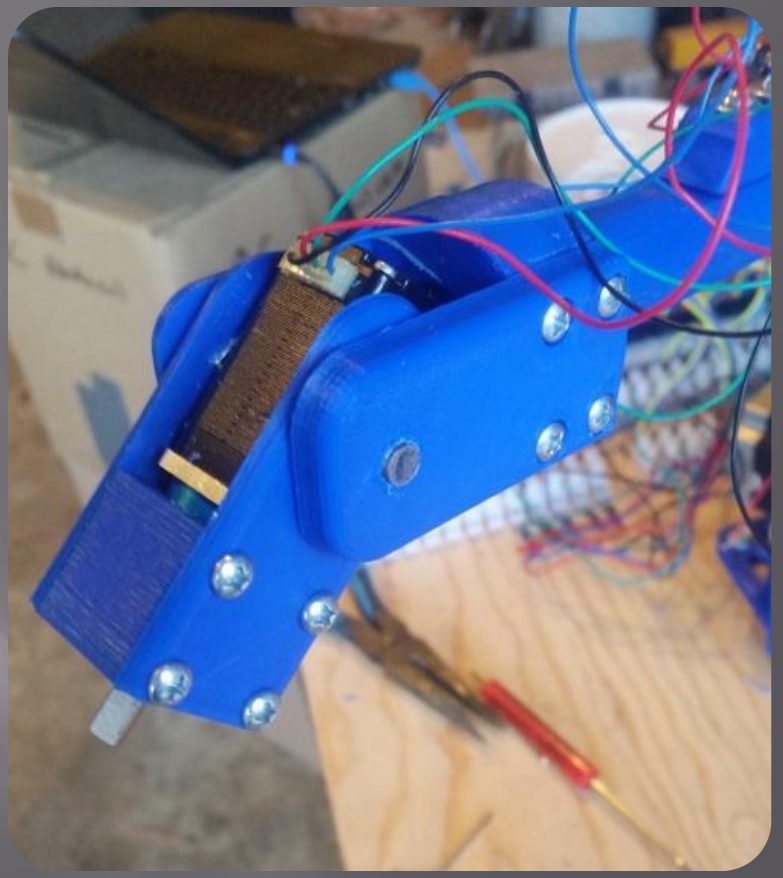


79) Install J5 turret left arm using #6 screws.

80) Install ¼″ bearing into right arm.

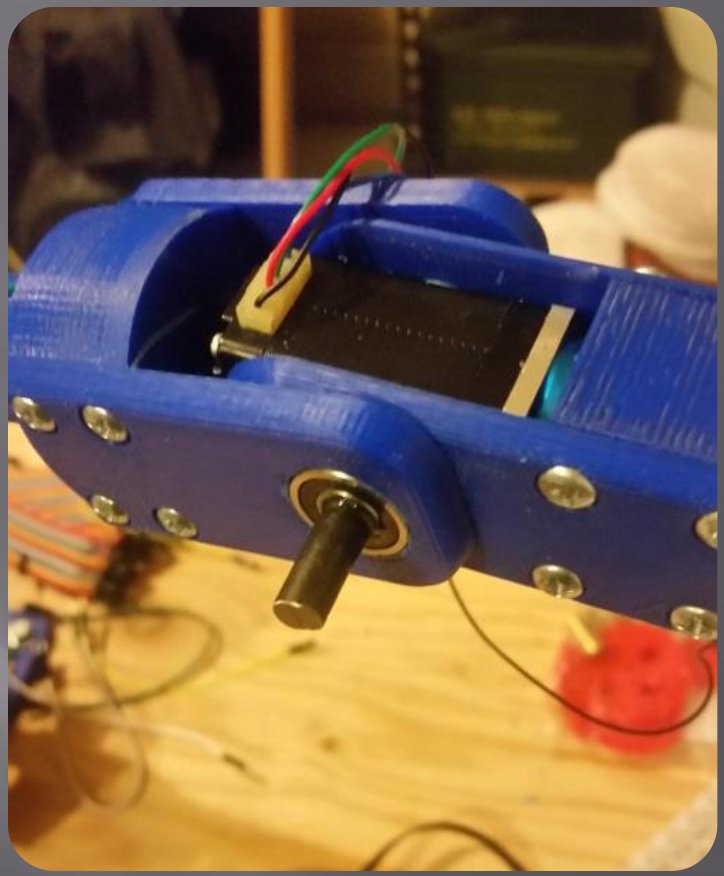


81) Install right arm using #6 screws.

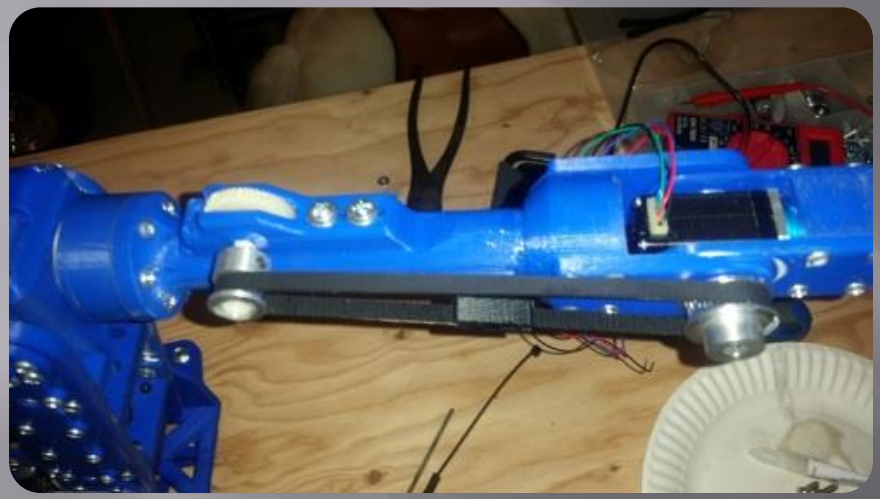


82) Install turret assembly into clevis assembly. use ¼″ dowel on right side as shown pressing the dowel through the right clevis arm into the ¼″ bearing.

83) Cut the head off of a ¼ - 20 bolt leaving ½″ of thread and ½″ of shaft (total 1″ long). Then grind a small flat on the end of the shaft end.



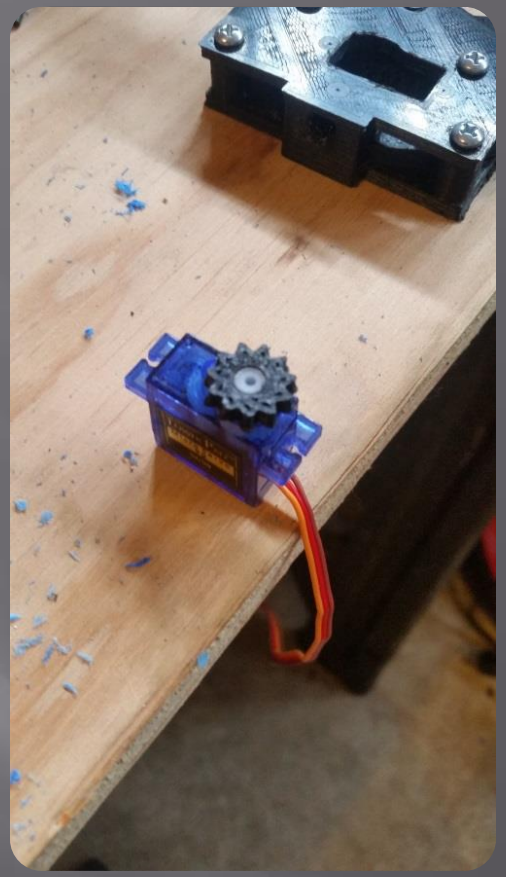
84) Apply epoxy to the end of the threaded Shaft you just made and then insert through The ¼″ bearing in the clevis arm and thread into the T nut in the turret arm. Once the epoxy has set this shaft should control the rotation of the turret assembly.



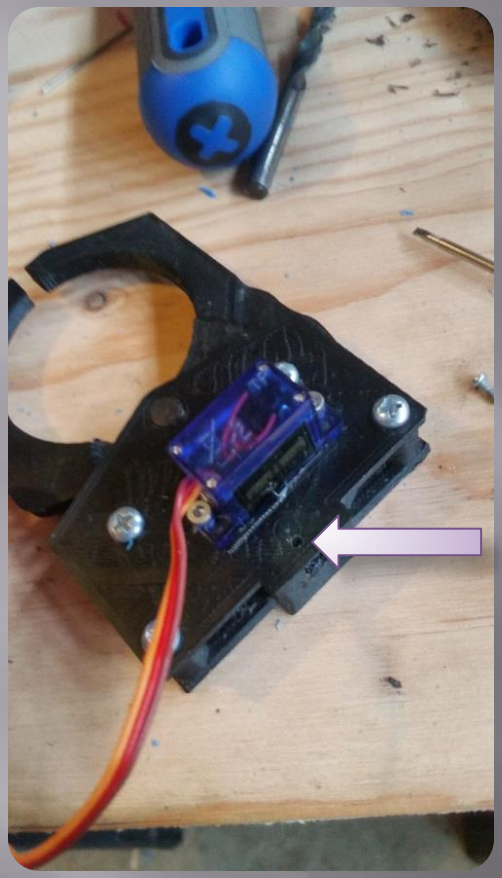
85) Install the aluminum belt drives as shown Then cut a length of belt to go around the drives, connect the belts using a printed belt coupler. Once you have the belt trimmed to the best length and installed and tensioned apply a couple drops of super glue where each end of the belt inserts into the coupler to make sure the belt doesn't slip out of the coupler. Also make sure the coupler is installed In the center between each of the aluminum drives.

86) Once the belt length is correct, the belt tension is set and the backlash Between the worm and ring gears is good then you can drill a couple holes at the end where shown and insert some 3mm screws to help secure the carrier to the boom.

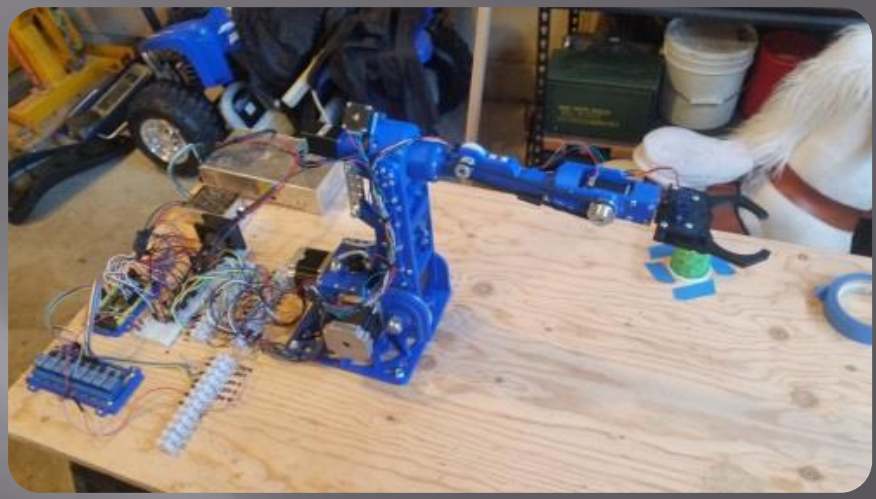
87) Assemble the gripper Components as shown. Use ¼″ dowel in the center at the Pivot point. You will need to clearance the holes in the jaws to be a free fit over the dowel. you may need to grind out the opening slightly to insert the servo gear assembly.



88) Install the gripper gear to the servo. You may need to clearance the gear center bore. Once I got it to the correct size it was a press fit onto the servo – I also used a drop of super glue on the end to secure.



89) Install the servo and Secure with 2mm screws. Drill a small hole for a 3mm Screw where shown.

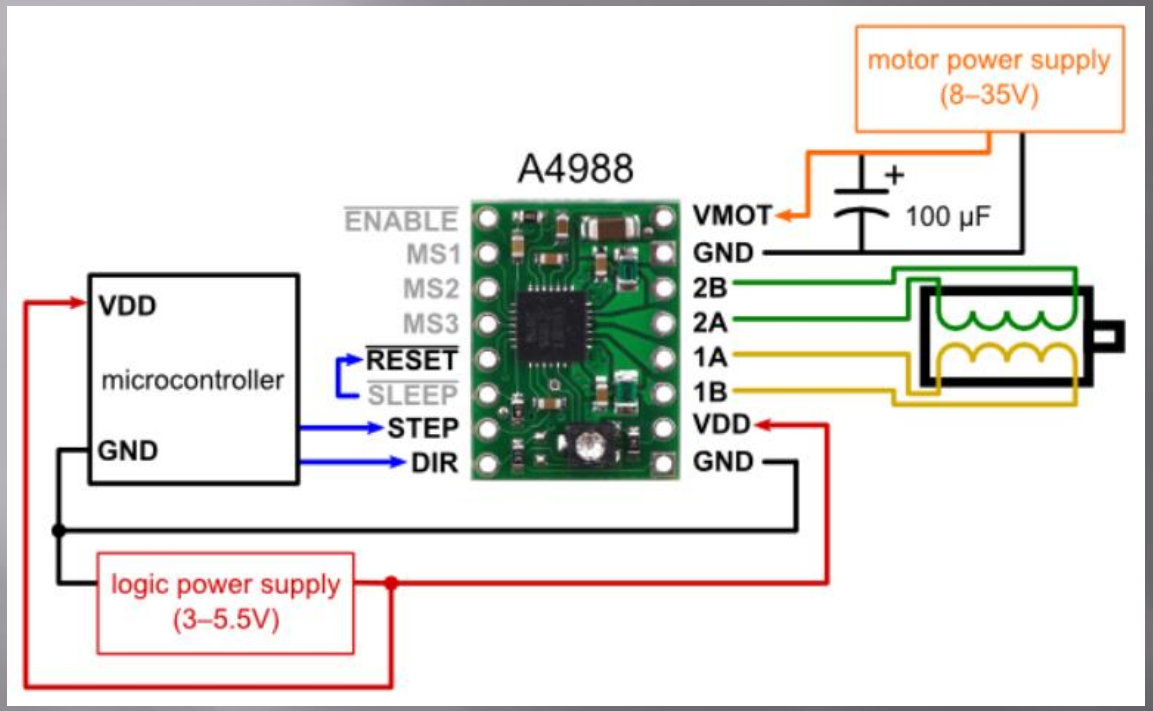


90) Install gripper and tighten 3mm screw to secure gripper to J6 shaft. Run all the wires down the robot Arm to the connection strip. Some of the wires will Need to be extended. I bought some extra wire and extended my wires soldering end to end and using shrink tubing over the connector. I've included some wire holders you can print and epoxy to the boom if you so desire. Make sure you leave enough slack for all your axis motions and that the wires are positioned so that they will not be pinched or pulled on when the robot is articulating.

ELECTRICAL AND ROBOT WIRING

Overview: Basically the control program reads the positions from the move J in your program and calculates how many motor steps it will take to complete the move. It then compiles the number of steps needed into a simple string and sends this to the Arduino board. The string it send the Arduino Is as follows “MJ” for move J then “A” for axis 1 followed by “0” or “1” for direction and then the number of steps and so on for each axis and then the string ends with an “S” followed by string value. So for example a move command that will move all motors in the + direction one full revolution (200 steps) at 100% speed would look like this “MJA1200B1200C1200D1200E1200F1200S100”. Once the Arduino receives this command it does some calculations to figure out which move requires the most steps and then divides the steps for the other motors into that value and figures out how many times to skip a particular motors step command so that all movements finish at roughly the same time.

The central or primary item that requires wiring is the stepper drivers. The stepper drivers receive a direction signal and step signal from the Arduino and then drive the stepper motor accordingly

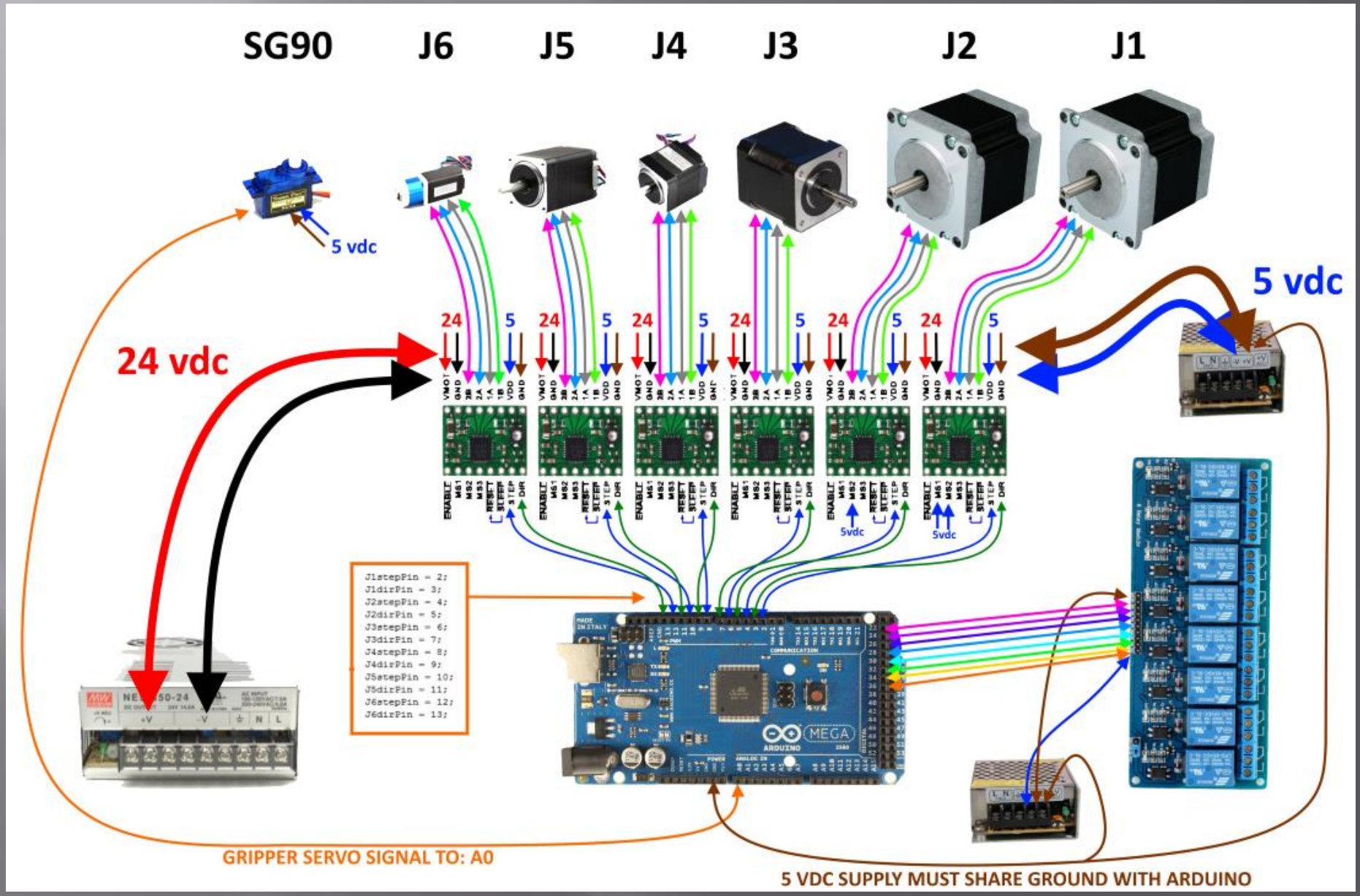


MS1	MS2	MS3	Microstep Resolution
Low	Low	Low	Full step
High	Low	Low	Half step
Low	High	Low	Quarter step
High	High	Low	Eighth step
High	High	High	Sixteenth step

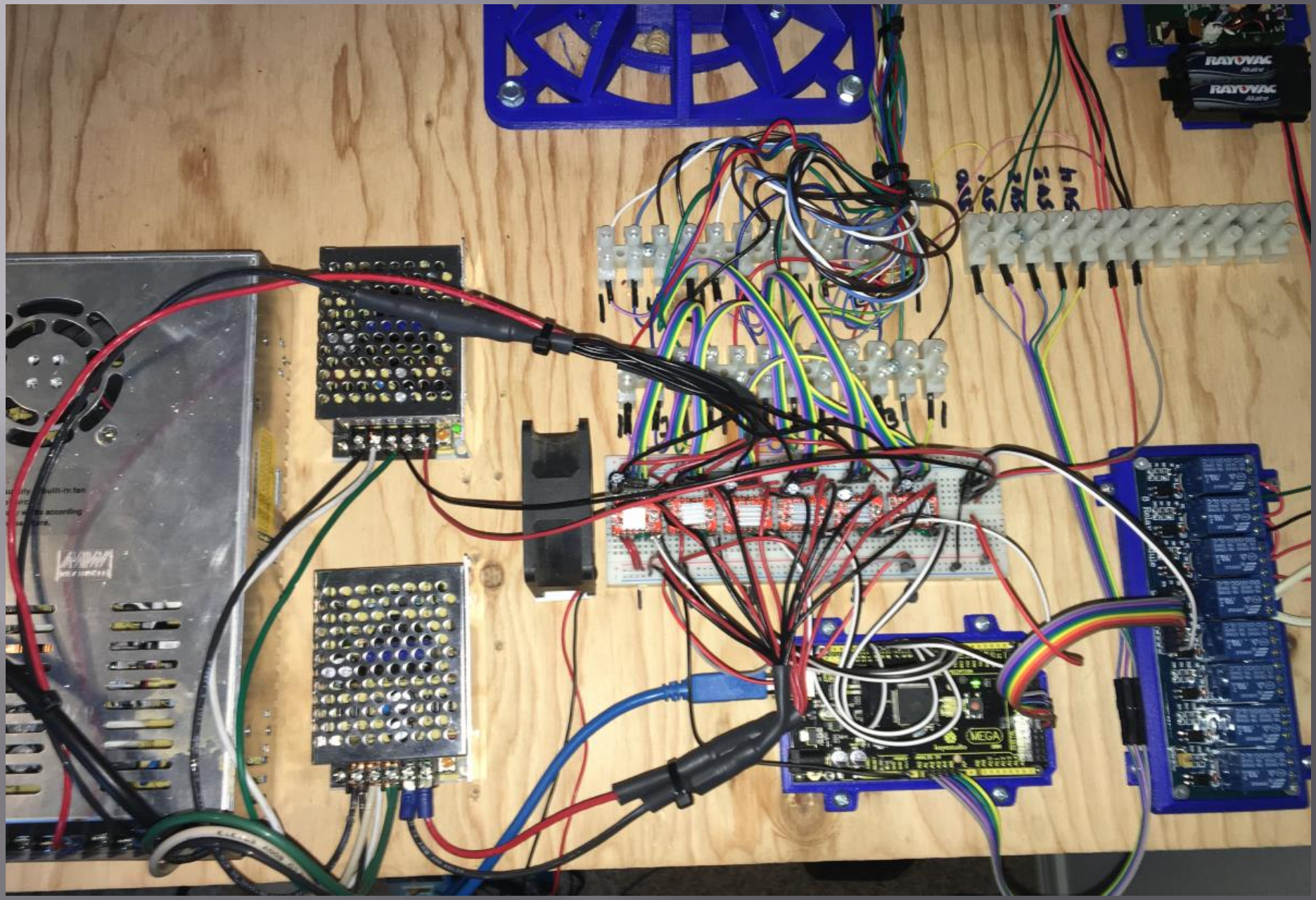
This chart shows the micro steps sent to the motor if MS1,2 or 3 are set high.

This is a generic schematic for the A4988 stepper driver. We need to wire 24vdc to the VMOT shown in orange and black. We then need 5vdc to the VDD – typically for smaller projects you could just use the 5vdc supply from the Arduino but it doesn't have the amperage to run 6 motors which is why we need the 5vdc power supply (one supply is enough to run the motors and a second supply is needed for the 8 channel relay board if you choose to install that). 2B,2A,1A,1B are wired to the stepper motor. The step and direction pins are signals wired from the Arduino. The reset and sleep are jumpered. MS1, MS2 and MS3 are used for micro stepping – this micro steps the motor and allows for a smoother motion (see chart above). You can see in the next schematic that we do use micro steps for J1 and J2 only being that they are geared quite tall and I needed to smooth the motion out a little bit.

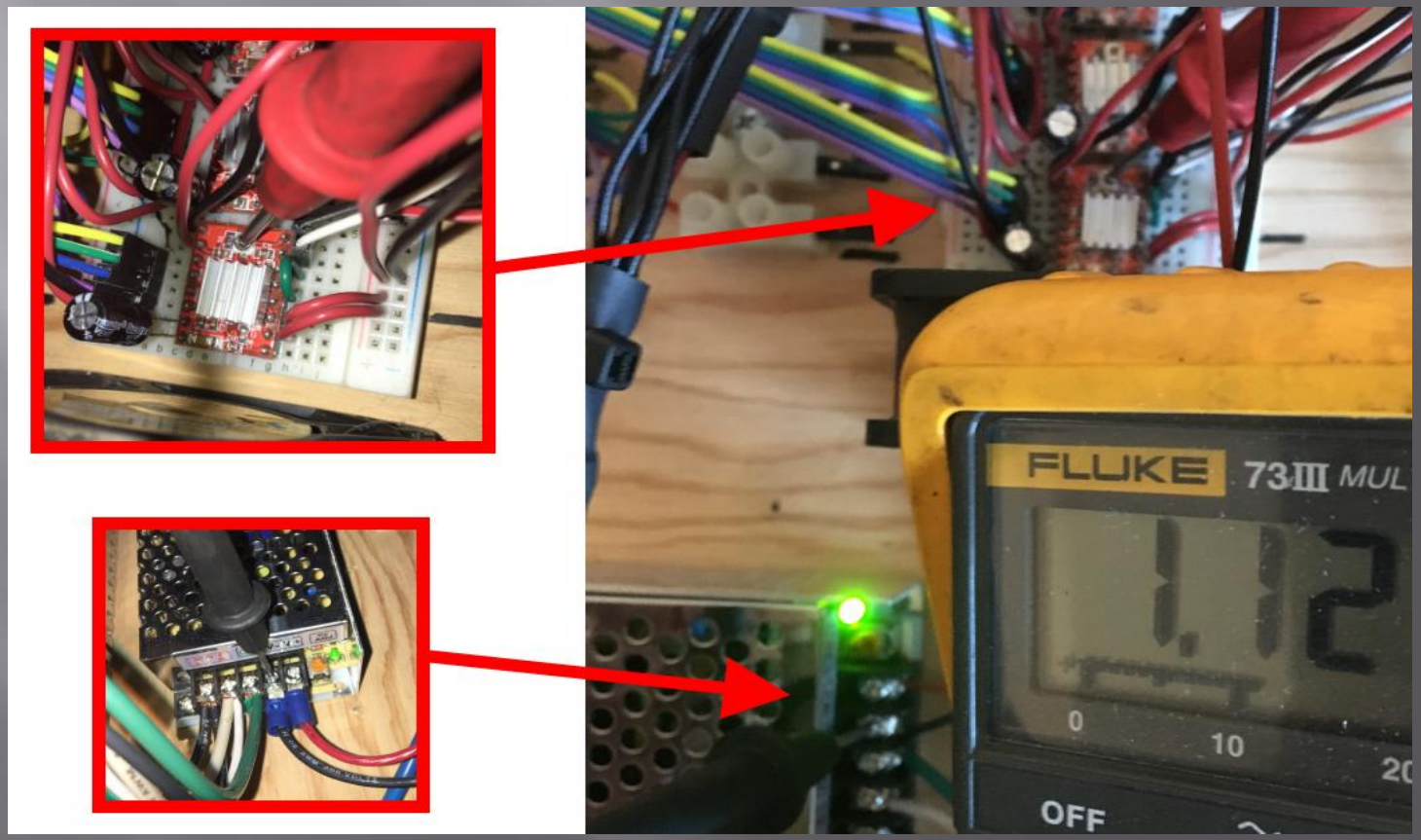
This is the full schematic for the robot including the 8 channel relay board. Note that J1 has 5vdc wired to MS1 and MS2 for 1/8th step micro stepping and J2 has 5vdc wired to MS2 for ¼ step.



This is a photograph of my installation.



The next thing we need to do is set the reference voltage for each stepper driver. If the voltage is too high you can damage the motor. The voltage is adjusted by turning the potentiometer on the stepper driver board. There are numerous tutorials online for adjusting the reference voltage on a 4988 driver – basically the formula is Vref=I*.04 or in other words current rating of the motor x .04 The higher the voltage the higher the torque. You can have performance issue if set too low. There are also a few of methods for setting the Vref without a meter just watching the motor performance. I started with the base setting and then dialed a few of them a little higher where needed – I know your not supposed to over drive them but I haven't had any issues. The picture below shows reading the voltage by putting the negative lead of your meter on the -5vdc and the positive lead directly on the terminal screw head for the potentiometer. To change the voltage just use a small screw driver to turn the potentiometer.



I ended up setting Vref to the values shown below on my robot – note the smaller nema 8 motor for axis 6 was the most problematic and I spent a fair amount of time tweaking it to get the motor to step accurately and consistently without any performance issues.

- J1 = 1 vdc
- J2 = 1 vdc
- J3 = 0.7 vdc
- J4 = 0.4 vdc
- J5 = 0.5 vdc
- J6 = .146 vdc

Now that wiring is complete and the Vref is set you can start working with the robot. The following 2 videos on YouTube cover calibration and programming.

Annin Robot - Calibration

https://youtu.be/jC1Iq60EnBI

Annin Robot - Programming

https://youtu.be/hFJe0j0nB_w